Letters to the Editor.

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Generalised Lines of Force.

LET me direct attention to a notable paper by Prof. E. T. Whittaker, in the Proceedings of the Royal Society of Edinburgh for November last.

It has often been discussed whether electric or magnetic lines of force were the more fundamental, and which might be regarded as the "cause" of the other; a discussion rather like the old controversy as to the direction of vibration in a polarised beam of light. Maxwell's theory satisfied the disputants by making both directions equally important.

In this paper Whittaker extends Faraday's theory of lines of force to electromagnetic activities in general, expressing the complex facts by aid of the space-time continuum of Minkowski, whereby any form of kinematics can be expressed as a sort of four-dimensional statics. The solenoids of Faraday are shown to be special cases of a more general kind of surfaces, called *calamoids,* which reduce to ordinary electric lines of force when the field is purely electrostatic, while they reduce to ordinary magnetic lines of force when the field is purely magnetic; so that the Faraday electric and magnetic lines are not two distinct and (as it were) rival things, but two limiting cases of the same thing. The essential solenoidal condition—strength inversely as cross-section—is retained if, instead of electric or magnetic force separately, the contra-variant $\sqrt{(E^2-H^2)}$ is employed, and if the cross-section is that of a calamoid.

Ordinary equipotential surfaces, whether electric or magnetic, are seen to be special cases of an "electro-potential" or "magneto-potential" [? ether-potential] surface, which reduces to one or other of them whenever the field becomes static. These electro-potential surfaces, in general, exist in the four-dimensional world of space-time; but when the field is static each surface is wholly contained within three-dimensional space, and is an ordinary equipotential surface.

The property of the Faraday lines of force, that they are everywhere perpendicular to the equipotential surfaces, is shown to be a case of the more general theorem that the calamoids are everywhere "half-orthogonal" to the electropotential surfaces; (half-orthogonality being the four-dimensional analogue of three-dimensional perpendicularity).

In electrostatics, the total strength of all the Faraday tubes which issue from a closed surface containing no electric charge is zero; similarly, in general radiation-fields, the total strength of all the calamoids which cross a closed surface is zero. This theorem provides an intuitive geometrical integration of the Maxwell-Lorentz equations of the electromagnetic field.

There are also elaborated generalised "divergence" and "curl" theorems, with a certain kind of absoluteness about them, since they are independent of the motion of any observer.

For much fuller and more trustworthy information Prof. Whittaker's paper must be referred to. He said something about it in Section A at the recent meeting of the British Association in Edinburgh, but I, for one, did not understand his meaning then, in the rush of Sectional procedure. The object of the present summary is merely to direct early attention to a paper which cannot be long overlooked.

December 28. OLIVER LODGE.

Units in Aeronautics.

WRITE the usual formula in aeronautics,

$$\frac{R}{S}=23{\cdot}7\left(\frac{V}{100}\right)^2,\ \text{lb/ft}^2,$$

in the Hospitalier notation, and the practical airman recognises that the resistance R, lb, over a surface S, ft², is at the rate 23·7 lb/ft² at a normal velocity of 100 f/s; and so on for any other velocity V, on the law of the square.

The airman pays no heed to any units except his foot and pound, and he has no use for any of the elaborate explanations of Mr. A. R. Low.

The factor 23·7 will be the result of experiment in the air-channel, reduced for air of standard conditions of barometer and thermometer on the ground.

But the air density is never measured in any of these experiments, and it is doubtful if the measurement has ever been carried out in any aeronautical laboratory.

In the early history of the Royal Society "weighing the air" was a favourite research. Charles II. bet Buckingham fifty guineas to one he would demonstrate the compression of air in his hollow walking-cane; but the other story of the fish in a bucket of water cannot be traced further back than Whateley, who is supposed to have invented it.

The air density arises in the formula of the treatise on aerodynamics on the idea that the formula is the expression of Newton's assumption that the resistance is due to the impact of inelastic air particles, as if air could be treated as a cloud of dust; and then at an air density w, lb/ft³, or better for calculation in thermo-aerodynamics, at a specific volume the reciprocal $C=1/w$, ft³/lb, Newton's formula becomes

$$\frac{R}{S}=w\frac{V^2}{g}=\frac{V^2}{gC},\ \text{lb/ft}^2;\ \text{ or }\ \frac{R}{S}=2wh,\ h=\frac{V^2}{2g}.$$

In this treatment the Equation of Continuity is ignored; the air particles should stop dead and fall down in a heap at the foot of the aeroplane, to be swept up as dust.

Thus the mysterious factor 0·00237 of the treatise on aerodynamics is the equivalent of w/g, and with $g=32{\cdot}2$, f/s², this makes $w=0{\cdot}0763$, lb/ft³, $C=13{\cdot}1$, ft³/lb, so that this standard air bulks 13 cubic feet to the pound, in round numbers.

Another way of expressing the law is to write it in the equivalent form

$$\frac{R}{S}=\left(\frac{V}{H}\right)^2,\ \text{lb/ft}^2,$$

so that H is the velocity at which normal resistance is 1 lb per square foot; then on the figures above H = 20·5 f/s, and this may be replaced by 20 in round numbers for practical calculation, making

$$\frac{R}{S}=25\left(\frac{V}{100}\right)^2.$$

Flying over the ocean the velocity would be expressed in knots, K, and with 12 knots the equivalent of 20 f/s the formula is

$$\frac{R}{S}=\left(\frac{V}{20}\right)^2=\left(\frac{K}{12}\right)^2,\ \text{lb/ft}^2;$$

simple numbers easily remembered.

In all these calculations Perry's dictum must be respected: that the accuracy of a formula is only the accuracy of its most inaccurate part.

Here the index 2 of the velocity, adopted for simplicity of calculation, is the part most subject to doubt, and then at this rate of the quadratic law the above numbers, 23·7, 24, and 25, are all equally

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suitable; their discrepancy is wiped out by small variation of air density or height of flight.

The practical airman will pay no heed to Mr. A. R. Low's elaborate explanation of the units employed in absolute measure (NATURE, January 5, p. 12). He has no use for poundal or slug units—fearful traps for the unwary and cause of great confusion of thought—and with the conceit to imagine they will pass current in the whole cosmos. But the rigour claimed for them is beginning to crack and show flaws under the merciless scrutiny of the new relativity.

Mr. Low is here coming to the rescue of the unhappy examinee, at the mercy of the whim of the examiner's text-book, and of the rigour demanded for the language employed there, ignored by the practical airman.

Divergence of language is never to disappear, as it seems, between science and engineering. The engineer refuses to budge when he finds he can arrive at a correct result in practice, and he ignores the rigour prescribed in the examiner's text-book as something to be thrown at the head of the examinee in his *conquête des diplômes*. G. GREENHILL.

Staple Inn, January 9.

Space and Æther.

THE relation of space and æther has been a subject of controversy. Three-dimensional absolute space has been regarded, before Einstein, as filled with a substantial æther. It is unnecessary to conceive the four-dimensional space-time of the relativists as so filled. If space-time is empty, is space also empty?

It seems to me that the crux of the difficulty is a wrong assumption that space-time is four-dimensional. Space-time is neither four-dimensional nor three-dimensional, but is two-dimensional. The orthodox analysis of the objective world down to the three fundamental entities of matter, space, and time has been incomplete. That which we call space also involves time. That which we call matter also involves both space and time. Thus what we call matter, space, and time should further be analysed as matter-space-time, space-time, and time where matter, space, and time with their new signification are fundamental entities. It is in this new sense that I shall use them hereafter.

Æther is the synthesis of space-times. It is matter-space-time. A synthesis is a petrified motion. We do not perceive the motion of æther because it is petrified. The motion in a space-time is independent of motion from space-time to space-time along the string that is æther. The so-called velocity of æther is not a change of space, but a change of matter.

Æther, being matter-space-time, partakes of the nature of all three. It has the density of matter, the rigidity of space, and the motion of time.

Æther is matter-space-time of no mind. The synthesis of matter-space-times of observing minds may be called hyper-æther—filling an absolute four-dimensional universe. Relatively to matter, æther is absolute. Relatively to mind, hyper-æther is absolute. The real is neither relative nor absolute, but is relatively absolute.

Einstein found that space-time was four-dimensional and that the universe was four-dimensional, and therefore argued that space-time was the universe. Therein lies his fallacy. His space-time is the two-dimensional section of a four-dimensional universe. There are two factors in evolution: persistence of identity and change of structure. As space-time is two-dimensional, its identity persists in the evolution from a three- to a four-dimensional universe. And as the world character changes, the internal structure of space-time changes. Einsteinian relativity is an anarchy. It marks a process of revolution, but does not attain a new position of stability.

Logic is not absolute, but is relative. The laws of logic of an absolute three-dimensional world are not the same as those of an absolute four-dimensional world. To study an absolute four-dimensional world we need a new logic, a new arithmetic, a new geometry, a new mechanics, and also a new science dealing not only with time as arithmetic does, not only with space as geometry does, not only with matter as mechanics does, but also with mind. On the recognition that time, space, matter, and mind contribute each a dimension to the universe I have been able to base an analytical geometry of the universe.

Space, in the sense of the arena of the three-dimensional universe, is matter-space-time, and may be regarded as filled with æther. The Euclido-Newtonian space-time and the Einsteinian space-time are non-material. But the latter is a stage of travail for the evolution of the former into a space-time with a new internal structure. The claim of the relativists to have demolished Euclid and Newton argues a want of the sense of historic perspective. Man does not progress by demolishing, but by building on, his past.

S. V. RAMAMURTY.

Trinity College, Cambridge, January 5.

Anisotropy of Molecules

DIRECT evidence that the molecules of gases are not spherically symmetrical and are anisotropic in their properties is furnished by the recent experiments of Lord Rayleigh, who has shown that the light scattered by molecules is, in general, not completely polarised when observed in a direction transverse to the pencil of light traversing the gas. The method used by Rayleigh, and by those who have repeated the experiments establishing this effect is a photographic one, the track of the primary beam of light as viewed through a suitably oriented prism of Iceland spar being recorded on a plate with long exposures. In view of the great interest of the phenomenon, it occurred to the present writer that it would be worth while to attempt direct *visual* observation and measurement of its magnitude. The chief obstacle is, of course, the extreme feebleness of the unpolarised part of the transversely scattered light. This has, however, been successfully overcome. By using the strongest possible illumination (sunlight), securing a perfectly black background, and very carefully screening the eye from extraneous light, it has been found possible to detect with dust-free air at atmospheric pressure the non-extinction of the track as seen through a nicol at any orientation. With carbon dioxide the effect is quite conspicuous, and visual determinations of its magnitude have been successfully made by Mr. K. R. Ramanathan working in the present writer's laboratory.

A very interesting question arises whether it is possible to establish the same effect by observations on the polarisation of skylight. As is well known, there is a marked defect in the polarisation of skylight in a direction removed 90° from the sun, which is, however, in the main, due to dust and condensed water-vapour in the atmosphere and the diffuse lighting up of the sky by self-illumination and by reflection from the earth's surface. It occurred to me that the elimination of the effects due to these disturbing factors does not present insuperable difficulties. The reflecting power of landscape (about 0·08 when covered by vegetation) is known, and its effect is therefore calculable. Dust and low-lying mists may be prac-

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